COMMENT

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LALO DE ALMEIDA/CONTRASTO/EYEVINE

A truck full of sugar cane crosses farmland in Brazil, a leader in bio-based ethanol production from the crop.

Five cornerstones of a global bioeconomy

Beate El-Chichakli and colleagues outline principles for coordinating bio-based industries to achieve many of the sustainable development goals.

More than 40 nations[1] are proposing to boost their 'bioeconomy' — the part of the economy based in biology and the biosciences. Around US$2 trillion of products in agriculture and forestry, food, bioenergy, biotechnology and green chemistry were exported worldwide in 2014, amounting[2] to 13% of world trade, up from 10% in 2007. These sectors are central to at least half of the UN Sustainable Development Goals (SDGs), from food security to ensuring energy access and health. But conflicting national priorities make it hard to align bioeconomy policies to meet the SDGs on a global scale.

Bioscience leaders such as the European Union, Japan and the United States see expanding the bioeconomy as a means of reindustrializing and creating wealth (see 'Bioeconomy breakdown'). Emerging industrial economies such as China and India see biotechnology as a nascent field of innovation in which they can quickly compete. Brazil, South Africa and Malaysia are investing to add value to their vast biological resources. Ecological sustainability is a prime concern in rich and industrializing countries; inclusive rural development and equitable sharing of resources is central in developing countries.

Knock-on effects of decisions made in one place may be felt elsewhere. The EU's plan to ecologically certify its bio-based products will impede producers in poorer countries who lack testing infrastructure. In India and Brazil, strict bio-piracy regulations, which aim to protect biodiversity and traditional knowledge, are failing to benefit local populations and are stalling international research in plant biodiversity.

Without agreed global priorities and assessment methods, it is hard to take into account such indirect effects and trade-offs. Global investments in information collection such as satellite tracking of biomass call for joint action. Nations will fund DNA barcoding of rare rainforest hardwoods or use genetic stock identification to manage fisheries only when such technologies are ▶

INNOVATIONS IN THE BIOECONOMY

Scoring Sustainable Development Goals

SDG 2: END HUNGER Food security is the top priority[5]. More-efficient animal production and meat substitutes are needed. Chicken is more sustainable than beef, owing to lower greenhouse-gas emissions and water needs. Genomic technologies will need to be applied to more foods, as they have been to dairy cattle, chicken, salmon, tilapia, rice and banana. Farmed seafood production must be boosted and will require new vaccines and molecular diagnostics to reduce antibiotic use, as well as sources of protein-rich feed.

SDG 3: ENSURE HEALTHY LIVES Sustainable medicines, such as biopharmaceuticals, and microbiome-based approaches are needed for infectious diseases such as malaria and epidemics including diabetes and obesity. For example, production of semi-synthetic artemisinin from microbially sourced artemisinic acid is an early success story for combining metabolic engineering and synthetic biology in the commercial production of drugs against malaria[6].

SDG 6: WATER AND SANITATION FOR ALL In developing countries, 90% of sewage and 70% of industrial wastes are discharged without treatment. Advances in biological wastewater treatment, including phosphorus removal and nitrification, hold potential if implemented more widely. Small, modular systems should be spread to remote communities, and large, intensive plants can cater for city-sized populations.

SDG 7: ENERGY FOR ALL Most developing countries have unreliable energy systems. Burning wood or manure leads to health problems, premature deaths and deforestation. Decentralized, modern solutions that combine bioenergy with other renewables are needed. For example, an Indian social enterprise has implemented dairy and biogas production and local mini-grids electrified by biogas from waste or by eco-briquettes.

SDG 8 & 9: SUSTAINABLE ECONOMIC GROWTH Combining rural regeneration with reindustrialization offers increased sustainability and inclusiveness. Brazil, a leader in bio-based ethanol production with around 300 operating sugar-cane or ethanol mills, is commercializing production of cellulosic ethanol. In Finland, a large biorefinery currently under construction will need only 200 people to run it but creates another 2,500 jobs across the value chain for growing, harvesting and transporting biomass.

SDG 11: SUSTAINABLE CITIES Biological principles — such as metabolisms, ecosystems and cycles — can be applied to help cities to function sustainably[1]. Local production and recycling systems minimize emissions and waste. Renewable resources, cultivation methods and biotechnology can close material and energy cycles and loops. For example, Edmonton in Canada is aiming to recover 90% of its organic waste and convert domestic waste into biofuels.

SDG 12: SUSTAINABLE CONSUMPTION Bio-based materials and chemicals are increasingly deployed in industries such as plastics processing, consumer goods, construction, pharmaceuticals and medical technology. Switching from fossil to bio-based materials would make a big difference in the chemicals sector, which has the third-largest emissions in industry, after steel and cement. Using enzymes in detergents has enabled consumers to significantly reduce washing temperature, for example.

SDG 13: COMBAT CLIMATE CHANGE Bio-based industries are active in carbon storage and mitigating climate change. Biotechnology companies are collaborating with heavy industry to make carbon dioxide emissions into bio-based chemicals and biofuels[7].

SDG 14: OCEANS, SEAS AND MARINE RESOURCES Illegal, unreported and unregulated fishing remains a major threat to marine ecosystems[8]. The need for traceability is urgent — one-third of the world's fisheries catch from 1950–2002 lacked species identification. The use of DNA barcodes in a global database — the Barcode of Life Data System — could be expanded to address traceability and fish fraud as well as yielding information on migration and dispersal.

SDG 15: TERRESTRIAL ECOSYSTEM With limited land area, agriculture must be intensified. And farming must decouple from the fossil-fuel industry. Advanced breeding technologies can avoid soil exhaustion and degradation. Self-fertilizing versions of food staples such as maize (corn), wheat, barley and rice, and fertilizing soils by microbial communities, could become feasible through bioengineering in a decade.

internationally used and enforced.

In November 2015, more than 700 experts from around 80 countries met in the first Global Bioeconomy Summit in Berlin. We, as members of the International Advisory Committee on the Bioeconomy (comprising 37 experts from around the globe who shaped the summit) outline the principles that were agreed and the steps needed to advance them, as well as illustrating how these can be applied to individual SDGs (see 'Scoring Sustainable Development Goals').

DIFFICULT BALANCE

A global bioeconomy must rebuild natural capital and improve the quality of life for a growing world population. It should balance managing common goods, such as air, water and soil, with the economic expectations of people. Three types of innovation will be needed: technological (such as systems to reduce emissions), organizational (changes in institutional behaviour) and social (such as job creation). For example, new sorts of sustainable building materials based on wood or lignin (a compound found in many plant cell walls) will need to be integrated into building codes. Also needed will be citizen-science evaluations of new houses, local wood-recycling and construction efforts. Sustainable food systems will require advances in plant breeding, food products, and farming and cultivation techniques, as well as steps to optimize shelf-life and food distribution, and social initiatives such as the revival of traditional crops, food-sharing platforms and low-meat diets.

Inclusiveness and knowledge transfer are important. For example, biotechnology infrastructure and skilled employees are found mostly in high-income countries, whereas local biological know-how and reuse culture are strong in developing countries. Supply chains should create local jobs, with manufacturing close to the raw-material base. For example, bioenergy mini-grids or bricks-from-waste production plants increase local energy access and jobs in rural India.

Regulatory frameworks for intellectual property, the access to and use of genetic resources, biosafety and the ethics of biosciences and industrial standards all need to be reviewed. Globally agreed standards on the measurement and definition of bio-based products — such as the carbon footprint and sustainability of bioplastics — are needed. A certifying and testing body must be independent and international to establish public confidence and enable countries that lack capacities to benefit from the results.

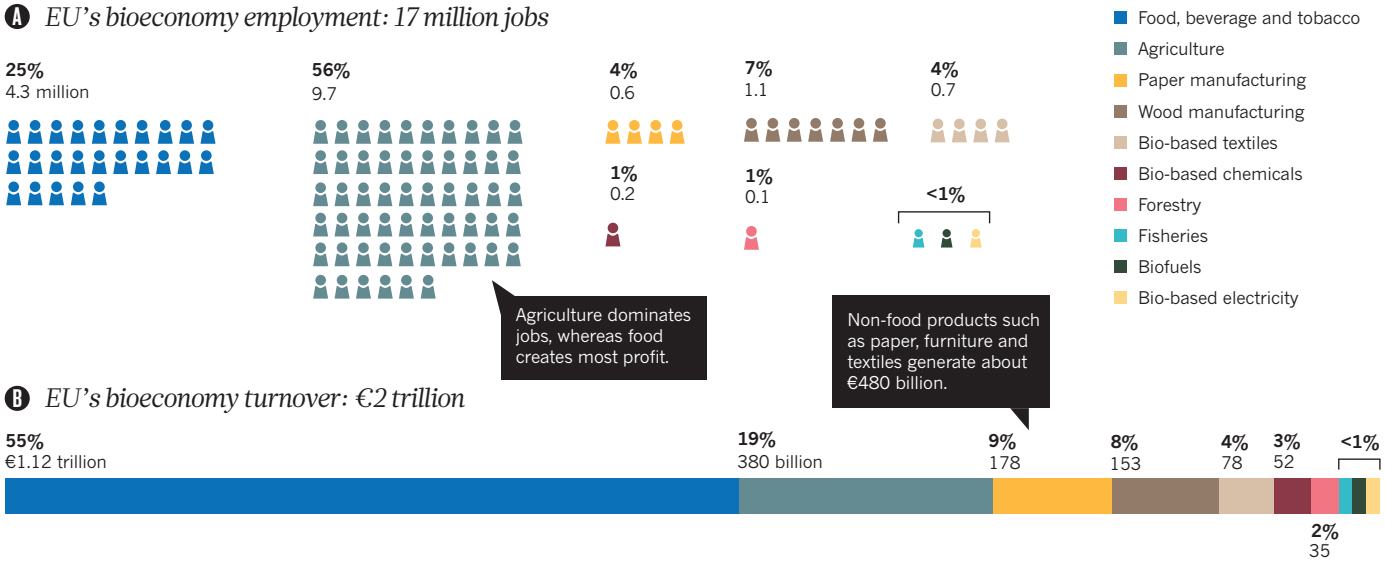
FIVE CORNERSTONES

Unifying principles for a global bioeconomy need to be put in place by international policy bodies, multilateral trade negotiators

BIOECONOMY BREAKDOWN

The European Union's biology-based industries account for 17 million jobs, or 8.5% of the region's workforce (**A**) and generate more than €2 trillion (US$2.2 trillion) annually (**B**). Equivalent statistics are unavailable elsewhere, but US industries producing bio-based products (non-food) account for about 4 million jobs and US$370 billion. India's bioeconomy surpassed US$4 billion in 2013. And Brazil's sugar-cane industry accounted for 2% of its gross domestic product and 4.5 million jobs in 2012.

SOURCE: REF. 9 (EU)



and the corporate sector.

First, international collaborations between governments and public and private researchers are essential for optimizing resource use and sharing knowledge. For instance, international initiatives that bring together bioscience and IT are needed in sustainable intensification and global soil mapping, to agree common protocols. The Food and Agriculture Organization of the United Nations (FAO) established a Sustainable Bioeconomy Working Group in 2016 and could develop such a forum.

Second, ways to measure the bioeconomy's development and its contributions to the SDGs need to be found. Priority targets, such as food security, and assessment criteria need to be agreed internationally, led by global organizations such as the UN and its subsidiaries. National monitoring systems should include the international dimension so that a country could examine how its practices might affect others. This will entail efforts to make related data openly accessible.

Third, bioeconomy initiatives need to be linked more closely with multilateral policy processes and intergovernmental discussions, particularly the SDG 2030 agenda and follow-ups to the Paris climate and Aichi biodiversity agreements. A UN body on bioeconomy needs to be set up to handle the coordination. Carbon pricing, the costing of other negative impacts (including indirect costs such as air pollution and climate change) and the removal of fossil-fuel subsidies are necessities for meeting the SDGs. Fossil energy received a staggering $5.3 trillion, or 6.5% of global gross domestic product, in post-tax subsidies in 2015[3].

Fourth, educators should collaborate internationally to define the knowledge, skills and competencies required for developing a bioeconomy that enhances the sustainable use of bio-based materials in manufacturing and in consumer products. This will require an interdisciplinary approach that emphasizes systems thinking, strategic planning and evaluating environmental, social and economic performance, as well as an understanding of technologies and local specifics. Governments should build international teaching and learning exchanges into research programmes. Open learning platforms would allow the sharing of curricula and training content.

Fifth, research-and-development support programmes are needed to encourage global collaborations in a few breakthrough projects. For example, 300 experts concluded[4] that collaboration in bioeconomy research would be most needed in the following areas: new food systems, bio-principled cities, sustainable aquaculture, biorefineries, artificial photosynthesis, consumer and citizen participation and global governance.

Discussions on these five cornerstones should begin now, so that structures can be in place before the next Global Bioeconomy Summit in 2017. ■

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